The Role of Open-Source Software in Innovation and Standardization in Radiology

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The use of open-source software (OSS), in which developers release the source code to applications they have developed, is popular in the software industry. This is done to allow others to modify and improve software (which may or may not be shared back to the community) and to allow others to learn from the software. Radiology was an early participant in this model, supporting OSS that implemented the ACR–National Electrical Manufacturers Association (now Digital Imaging and Communications in Medicine) standard for medical image communications. In radiology and in other fields, OSS has promoted innovation and the adoption of standards. Popular OSS is of high quality because access to source code allows many people to identify and resolve errors.

Open-source software is analogous to the peer-review scientific process: one must be able to see and reproduce results to understand and promote what is shared. The authors emphasize that support for OSS need not threaten vendors; most vendors embrace and benefit from standards. Open-source development does not replace vendors but more clearly defines their roles, typically focusing on areas in which proprietary differentiators benefit customers and on professional services such as implementation planning and service. Continued support for OSS is essential for the success of our field.

Key Words: Open-source software, DICOM, HL-7, IHE, innovation

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INTRODUCTION

There is an active community in the world known as the open-source community. Although this community has been in existence for a few decades, it has received attention after the success of the Linux operating system and Apache's Web server software. Linux is now embraced by most major computer and software vendors, including IBM, Hewlett-Packard, and Dell. Apache's is by far the most common Web server software, with over 70% of the Internet being served from servers running it [1].

Open-source software (OSS) is not new to radiology. One of the earliest efforts was the creation of the "central test node" software by the Electronic Radiology Laboratory of the Mallinckrodt Institute, under contract from the Radiological Society of North America. This code was both a publicly available reference implementation of the then-new version 3 of the ACR–National Electrical Manufacturers Association standard (now known as Digital Imaging and Communications in Medicine [DICOM] 3.0) and the reference model against which vendors could test their ability to exchange data. Since that time, other open-source implementations of DICOM have been released, as well as many other tools useful to radiology. It is our belief that open-source development has played and will continue to play a critical role in accelerating the adoption of open standards in our community.

The purposes of this article are to (1) describe OSS and compare it with other software-licensing models; (2) describe the relationship among OSS, academia, and industry; and (3) discuss the potential impact of OSS on radiology's future.

WHAT IS OSS?

First, to understand OSS, one must understand what source code is. Source code is a program written by a programmer before it is compiled into a machine-executable format. This means that anyone with modest computer skills can make any number of copies of the pro-

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gram. With moderate skills, one can read the code and learn how an algorithm contained within it works. And one can modify that algorithm to meet specific needs. Source code allows one to use and maintain the program far beyond copying the compiled binary or executable form. Open-source development means that developers share a program's code with one another in the hope of developing a better product and distributing the cost of development. Open-source developers share the beliefs that "many eyes makes problems shallow" and that different perspectives will add to the overall product [2].

Open-source software does not dictate a single licensing model. The copyright statements included with OSS packages are sometimes known as "copylefts" because the copyright is obtained to prevent some entity from copyrighting the material and removing it from public access. Open-source license statements are designed to ensure that the source code cannot be removed from public access and is maintained in 1 uniform application as much as possible.

There are several license models for OSS, but 2 prominent ones are associated with open source development: the Berkeley Software Distribution (BSD) and the GNU Project General Public License (GPL). The BSD license model essentially says you may take a program and do with it as you wish, including using it in a commercial product [3]. The major provisos are that you must credit the author(s) in the source code or reproduce the copyright in binary distributions, you may not sue the creator if the software doesn't do what you think it should, and you may not use the creator's name to endorse the product. One example of this is Apple's use of the BSD operating system as the core of its OS X. The BSD license is considered the business-friendly license because companies can use code, modify the code, and even sell the code without paying its authors. The central test node DICOM reference implementation was released with a BSD-style license. Many companies do contribute back to OSS projects with BSD-style licenses even though they don't have to, because it is far easier than trying to maintain a parallel copy of the source code and continually having to synchronize with updates as they occur. It can also direct an OSS project in a way that is advantageous to a company.

The GPL requires that if you release any derivative product (eg, a modification to the source code) to the public, you must share its source code with the original creators [4]. This is done with the intention that improvements be made available to the public in a coherent fashion. Many groups that create software will use GPL-style licenses for noncommercial use (eg, academic and home use) but have more restrictive licenses for commercial use. This dual-license model may have provisions that allow free use for end users but request royalties when the software is sold as part of a solution by a vendor. The idea is that the software is free to use, but if you make money off someone else's software, they deserve a portion of the profits. Most involved would agree that OSS is about freedom, with the BSD license seeming like "free beer," whereas the GPL focuses on "free speech." These are important philosophical differences that are relevant for the academic community.

Freeware and shareware may seem to be similar to OSS, but they are fundamentally different. With either, users have the executable software only, without the possibility of modifying it or seeing the source code to understand how it works.

In the case of a commercial software license purchased from a vendor, there is usually a license agreement that restricts how the purchaser may use the software. The license terms vary widely, but typically, they allow you to execute one copy of the software. If you wish to use additional copies, they must be purchased. In some cases, backup copies may be made, but often, there are deliberate attempts by vendors to make such copies difficult to make.

WHAT IS OSS GOOD FOR?

It is our contention that OSS is vital to academic radiology because standards and open methods are important to us. The DICOM standard has enabled a great deal of innovation and business in the radiology marketplace to occur. Software is the embodiment of many standards or protocols. Open access to those protocols and visibility of how they are implemented are crucial to the adoption of those standards. The ability to see exactly how algorithms operate is critical to understanding the methods, much as visiting a laboratory is critical to understanding how techniques really work. Openness with algorithms promotes openness with data. Open-source development need not require that the first or only sharing be via Web-distributed source code. It is entirely appropriate to produce academic publications describing the algorithms as well as data and possibly to provide a reference to the source code and data set. In fact, releasing the source code and data should be viewed as a critical component of the peer review method, just as peer review is an essential part of the validation and adoption of scientific hypotheses.

Raymond [2] suggested that the parity between OSS and academia stems from their economic models; specifically, he noted that both systems are gift cultures:

> In populations that do not have significant material-scarcity problems with survival goods. . .abundance makes command relationships difficult to sustain and exchange relationships an almost pointless game. In gift cultures, social status is determined not by what you control but by what you give away.

The economic conditions shaping both academia and OSS allow for the development of gift cultures, in which members give away knowledge and acquire reputations on the basis of what they give.

The gift culture in academia is one of the main reasons for rapid advancements in medicine and science. Willingness to share advances with others, who can take those advances and add their unique contributions, further advancing the field, is critical to vitality and overall growth. This has largely occurred via scientific literature in past decades. Now, as computing technology and software become more critical, sharing computing methods becomes a parallel to academic journals.

Raymond [2] also suggested that this model's ubiquity makes it "the globally optimal way to cooperate for generating (and checking!) high quality creative work." Both academia and open-source development benefit from the quality control created by gift cultures. Open-source development communities exploit the power of peer review to facilitate the debugging process of feature enhancement. Open-source software projects are generally characterized by rapid, incremental release schedules, in which limited extra functionality is added in each release [5].

Many in the open-source community have demonstrated that open-source development can improve quality and lower costs because of the many eyes reviewing the code [2]. It is less clear, however, whether this can be broadly applied outside of the computer science arena because of the fewer people with both science-specific and programming skills.

WHEN DOES OSS NOT MAKE SENSE?

Open-source software should not be viewed as an all-or-nothing proposition that one is either for or against. Those promoting OSS are often characterized as religious zealots whose primary goal is to destroy successful software companies. We believe that there is a role for proprietary software and software companies. Defining the correct places to promote and use OSS is the critical question. We believe that OSS should be viewed as the solution for certain business needs, primarily infrastructural needs. In areas in which there are defined standards or open protocols and few business differentiators, OSS makes sense. A proprietary piece of software that does not adhere to standards for infrastructure functions will cost more in the long run; you must implement nonstandard interfaces at the start, and undo that effort when the proprietary system is replaced. Furthermore, OSS is likely to be the highest quality implementation of standards, because many people can review the code to ensure that it properly implements the standard.

On the other hand, there is great potential to differentiate your business in arenas in which standards do not exist. Often, standards exist for the communication of information, but how that information exists in a database is usually not codified. In this case, a clever database design may lead to significant business value and may be a case in which a proprietary design or product makes sense.

Another case in which OSS is probably not the correct choice is for mission-critical applications for which no vendor can provide assistance with implementation and maintenance, and local resources are insufficient to perform these tasks. As described below, this is a critical factor in the success of OSS. Without a vendor to support an application, OSS cannot be considered business grade.

An important consideration in the decision to use OSS is the life cycle of a software package. The concern is that there is no guarantee that the original creator (or anyone else) will maintain his or her creation. This is a legitimate concern but is not unique to OSS. In fact, some might argue that the availability of the source code is a stronger guarantee of long-term viability than a long-term maintenance agreement with a smaller vendor.

OSS AND THE PRACTICE OF RADIOLOGY

A number of OSS packages are of great value to imaging researchers. These range from basic communications packages to packages that perform sophisticated image analyses and measurements. Any such review will necessarily be incomplete and will become less complete and less accurate as time passes. Therefore, we instead point you to dynamic sources and methods for getting current open-source radiology projects. One of the dominant players in the OSS arena (but not limited to radiology) is Sourceforge (http://sourceforge.net). Sourceforge is a Web site that hosts open-source projects of all types. Although this Web site is not specific to radiology or medicine, doing a search for a term such as *radiology* or *DICOM* will reveal a number of software packages addressing these areas. These include tools for image viewing, manipulation, and management. There are some Web sites focused on open-source projects in medicine (http://www.openmed.com) and some specific to radiology (http://www.openrad.com).

OSS AND THE BUSINESS OF RADIOLOGY

For many, OSS implies that software is free and that all information technology costs will drop dramatically. In fact, studies have shown that the majority of information technology costs are for implementation, maintenance, and support, though those costs are often hidden or rolled into software purchases. With OSS, the software acquisition costs are essentially zero, putting the implementation, maintenance, and support costs in the spotlight. This illumination of the true cost structure would shift most vendors' business models from that of a capital good provider to that of a service provider (eg, hospitals would purchase implementation and support contracts for the OSS they choose). This has occurred for some of the OSS projects we have described (eg, Redhat for Linux and MySQL AB for MySQL). This shift from capital expense to operational expense could have an effect on budget planning, and mechanisms to convert these may represent a business opportunity.

Because software applications and their maintenance and improvements are owned by hospitals, there is no longer a profit motive to force the obsolescence of the software. Indeed, it would likely be advantageous for service providers to stretch the life of current implementations, because they are the ones most likely to continue to maintain the software. In the software capital purchase model, vendors are motivated to obsolesce current software to stimulate future sales.

OSS AND THE FUTURE OF RADIOLOGY

Radiology has been a leader in the development of many imaging modalities and is the clear leader in imaging informatics. But we cannot rest on technologies such as DICOM and Integrating the Healthcare Enterprise. We must continue the advance by focusing on other technologies, such as standardized lexicons (RadLex; see http://www.rsna.org/radlex) for describing findings and new image processing methods (such as the Insight Segmentation and Registration Toolkit; see http://itk.org). Open-source software often significantly lowers the cost of entry to standards-compliant practice and allows early adopters to implement "workarounds" to shortcomings of the standards until amendments are made. For these reasons, open-source development is a key to the rapid adoption and improvement of standards in radiology.

There is also the potential for more rapid scientific advancement due to the sharing of information and software. The National Institutes of Health Roadmap [6] identifies the need for increased collaboration and sharing of information between investigators to allow medicine to make the same leap to "big science" that other scientific fields (such as physics) made a few decades ago. Because software is the key to both information exchange and knowledge derivation from data, OSS would seem to be a key element in accelerating our conversion to big science.

KEYS TO THE SUCCESS OF OSS

There are at least 2 critical components to a successful OSS project. First, there must be an energetic advocate (sometimes referred to as a "white hat"). This is typically 1 person who has a vision of the problem to be addressed and the resources to direct development of the software solution (and usually the resources to implement the first version). Second, there must be a community of others who also see this problem. The role of the community is to test and implement the software in their environments, finding problems and then either fixing them or characterizing the problems well enough to allow the advocate to fix the problems. The community also plays a role in improving the application with ideas for new features, better algorithms, and so on. A third component of OSS success (which is not always necessary) is a vendor that can make a successful business out of selling service and support for that package and that is motivated to improve it as well. A major impediment to the utilization of OSS by many businesses is concern about service and support: they often need help to implement a software package, and they need guarantees that the software will be durable, typically in the form of a maintenance contract.

Because many successful OSS projects have accomplished these steps without any external support, it is assumed that radiology OSS projects can also be "low budget." One key factor that determines if this is true is if the white hat is a programmer who can do much of the early work. In computer science, there are many who see a problem (eg, the need for an operating system or a Web server) who can also design and develop an application. There are far fewer people in radiology who can do both, and the time demands on radiologists are often greater than for a programmer perhaps working in academia. Academic computer scientists also have greater access to graduate students with strong programming skills than do physicians.

Another factor in (but not a requirement for) success is money. Although there are examples of low-budget OSS projects that were successful, money is likely to be a big factor in areas outside the software industry. Even within the software industry, it often requires large sums of money to catalyze a group of people to accept and ultimately champion an OSS project. The recent Eclipse project (http://eclipse.org) was started largely because of a $40 million seed grant from IBM. Within medicine, the Insight Segmentation and Registration Toolkit project has been fairly successful in providing a home for standard and cutting-edge image processing algorithms that can be used within applications. The National Library of Medicine has spent approximately $10 million in bringing that project to fruition. The Radiological Society of North America also invested seed money to get DICOM reference implementations into the public forum. But there are examples of great radiology-related OSS projects (eg, dcm4che, OSIRIS, ImageJ) that had no specific funding.

CONCLUSIONS

Openness is crucial in academia; it is essential for peer review and the validation of results and for the adoption and advancement of standards that allow groups to effectively exchange information. As computers become a more critical element of our work, OSS will be increasingly necessary to the success of academia. But OSS cannot be expected to grow on its own. We must recognize its importance and provide mechanisms to support its growth and adoption. Our goal must not be to eliminate vendors, for they will be valuable partners. Rather, the goal is to advance science and medicine by promoting appropriate information sharing and minimizing the duplication of effort in tool development.

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